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JC535 U.S. PTO 09/19/00

JC525 U.S. PTO 09/664705 09/19/00

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PTO/SB/05 (4/98)
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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 C.F.R. § 1.53(b))

Attorney Docket No.	8389-013
First Inventor or Application Identifier	NADLER, Shachar
Title	METHOD AND APPARATUS FOR MONITORING TRACE
Express Mail Label No.	

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: **Assistant Commissioner for Patents**
Box Patent Application
Washington, DC 20231

1. [✔] * Fee Transmittal Form (*e.g., PTO/SB/17*)
   (*Submit an original and a duplicate for fee processing*)
2. [✔] Specification [*Total Pages* 27]
   (*preferred arrangement set forth below*)
   - Descriptive title of the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to Micro fiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings (if filed)
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
3. [✔] Drawing(s) (*35 U.S.C. 113*) [*Total Sheets* 12]
4. Oath or Declaration [*Total Pages* 1]
   a. [ ] Newly executed (original or copy)
   b. [✔] Copy from a prior application (37 C.F.R. § 1.63(d))
   (*for continuation/divisional with Box 16 completed*)
      i. [ ] DELETION OF INVENTOR(S)
      Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. §§ 1.63(d)(2) and 1.33(b).

NOTE FOR ITEMS 1 & 13: IN ORDER TO BE ENTITLED TO PAY SMALL ENTITY FEES, A SMALL ENTITY STATEMENT IS REQUIRED (37 C.F.R. § 1.27), EXCEPT IF ONE FILED IN A PRIOR APPLICATION IS RELIED UPON (37 C.F.R. § 1.28).

5. [ ] Microfiche Computer Program (*Appendix*)
6. Nucleotide and/or Amino Acid Sequence Submission (*if applicable, all necessary*)
   a. [ ] Computer Readable Copy
   b. [ ] Paper Copy (identical to computer copy)
   c. [ ] Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

7. [ ] Assignment Papers (cover sheet & document(s))
8. [✔] 37 C.F.R.§3.73(b) Statement (*when there is an assignee*) [ ] Power of Attorney
9. [ ] English Translation Document (*if applicable*)
10. [ ] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
11. [ ] Preliminary Amendment
12. [✔] Return Receipt Postcard (MPEP 503) (*Should be specifically itemized*)
13. [✔] * Small Entity Statement(s) (*PTO/SB/09-12*) [✔] Statement filed in prior application, Status still proper and desired
14. [ ] Certified Copy of Priority Document(s) (*if foreign priority is claimed*)
15. [ ] Other: ....

16. If a CONTINUING APPLICATION, *check appropriate box, and supply the requisite information below and in a preliminary amendment:*

[✔] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No: __________

Prior application information: Examiner __________ *Group / Art Unit:* __________

For CONTINUATION or DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 4b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

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PATENT TRADEMARK OFFICE

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Patent fees are subject to annual revision.
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TOTAL AMOUNT OF PAYMENT ($) 345.00

Complete if Known	
Application Number	
Filing Date	
First Named Inventor	NADLER, Shachar
Examiner Name	
Group / Art Unit	
Attorney Docket No.	8389-013

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1. ☐ The Commissioner is hereby authorized to charge indicated fees and credit any overpayments to:

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FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	690	201	345	Utility filing fee	345.00
106	310	206	155	Design filing fee	
107	480	207	240	Plant filing fee	
108	690	208	345	Reissue filing fee	
114	150	214	75	Provisional filing fee	

SUBTOTAL (1) ($) 345.00

2. EXTRA CLAIM FEES

			Extra Claims		Fee from below		Fee Paid
Total Claims	20	-20** =		X		=	0.00
Independent Claims	3	- 3** =		X		=	0.00
Multiple Dependent						=	0.00

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Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	78	202	39	Independent claims in excess of 3
104	260	204	130	Multiple dependent claim, if not paid
109	78	209	39	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 0.00

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet.	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	380	216	190	Extension for reply within second month	
117	870	217	435	Extension for reply within third month	
118	1,360	218	680	Extension for reply within fourth month	
128	1,850	228	925	Extension for reply within fifth month	
119	300	219	150	Notice of Appeal	
120	300	220	150	Filing a brief in support of an appeal	
121	260	221	130	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,210	241	605	Petition to revive - unintentional	
142	1,210	242	605	Utility issue fee (or reissue)	
143	430	243	215	Design issue fee	
144	580	244	290	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Petitions related to provisional applications	
126	240	126	240	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	
146	690	246	345	Filing a submission after final rejection (37 CFR § 1 129(a))	
149	690	249	345	For each additional invention to be examined (37 CFR § 1.129(b))	

Other fee (specify) ____________

Other fee (specify) ____________

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SUBMITTED BY Complete *(if applicable)*

Name *(Print/Type)*	Stephen M. Beney	Registration No. *(Attorney/Agent)*	41,563	Telephone	(416) 364-7311
Signature	[signature]			Date	September 15, 2000

WARNING:

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Applicant or Patentee: SHACHAR NADLER
Seria[redacted] Patent No.: _
Filed[redacted]Issued:
For: METHOD AND APPARATUS FOR MONITORING TRACE CONSTITUENTS IN A FLUID

Attorney's
Docket No: 8389-003

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS
(37 CFR 1.9(f) and 1.27 (c)) - SMALL BUSINESS CONCERN

I hereby declare that I am

[ ] the owner of the small business concern identified below:
[X] an official of the small business concern empowered to act on behalf of the concern identified below:

NAME OF CONCERN UNISEARCH ASSOCIATES INC.
ADDRESS OF CONCERN 222 SNIDERCROFT ROAD, CONCORD, ONTARIO, CANADA, L4K 1B5

I hereby declare that the above identified small business concern qualifies as a small business concern as defined in 13 CFR 121.3-18, and reproduced in 37 CFR 1.9(d), for purposes of paying reduced fees under section 41(a) and (b) of Title 35, United States Code, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the business concern is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power to control the other, or a third party or parties controls or has the power to control both.

I hereby declare that rights under contract or law have been conveyed to and remain with the small business concern identified above with regard to the invention, entitled **METHOD AND APPARATUS FOR MONITORING TRACE CONSTITUENTS IN A FLUID** by inventor **SHACHAR NADLER** described in

[X] the specification filed herewith
[ ] application serial no. ____________, filed _________.
[ ] patent no. ______________, issued ___________.

If the rights held by the above identified small business concern are not exclusive, each individual, concern or organization having rights to the invention is listed below* and no rights to the invention are held by any person, other than the inventor, who would not qualify as an independent inventor under 37 CFR 1.9(c) if that person made the invention, or by any concern which would not qualify as a small business concern under 37 CFR 1.9(d), or a nonprofit organization under 37 CFR 1.9(e). *NOTE: Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)

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[ ] INDIVIDUAL [ ] SMALL BUSINESS CONCERN [ ] NONPROFIT ORGANIZATION

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NAME OF PERSON SIGNING H / SCHIFF
TITLE OF PERSON OTHER THAN OWNER PRESIDENT
ADDRESS OF PERSON SIGNING 222 [illegible]

SIGNATURE [illegible] DATE [illegible]

BP #8389-013

BERESKIN & PARR **UNITED STATES**

Title: METHOD AND APPARATUS FOR MONITORING TRACE CONSTITUENTS IN FLUE GASES, UTILIZING A LASER BEAM

Inventor: SHACHAR NADLER

Title: METHOD AND APPARATUS FOR MONITORING TRACE CONSTITUENTS IN FLUE GASES, UTILIZING A LASER BEAM

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation of application serial no. 08/508,505 filed July 28, 1995, now abandoned.

FIELD OF THE INVENTION

This invention relates to a method and apparatus for monitoring and measuring trace constituents in a fluid, and more particularly relates to monitoring and measuring trace constituent gases in the atmosphere. It is particularly concerned with apparatus suitable for remote sensing and monitoring of such constituents.

BACKGROUND OF THE INVENTION

Pollution is of ever increasing concern. One type of pollution that is of particular concern is atmospheric pollution by various gases. Consequently, it is becoming desirable to monitor gases, such as stack gases, emitted by industrial plants. This enables air quality to be monitored and emission standards to be met. It can also be a valuable process control tool, since variations in stack gases can be indicative of changes in process conditions and possible inefficiencies in the plant being monitored.

Various proposals have been made for monitoring stack gases, but most of them suffer from a number of deficiencies. For example, in U.S. patent 3, 517,190, there is a relatively old proposal for monitoring a smoke plume from a stack. It is illuminated with radiation of a broad spectral range. A remotely positioned receiver, in proximity to the source receives scattered radiation. A processing technique is used to develop signals from the scattered radiation and to analyze these signals to measure the quantity of an absorbing gas of interest in the plume. Here, both the source and the detector are located remotely from the plume, and must be accurately aligned

to illuminate the plume and receive the radiation reflected back. The patent notes that various conditions need to be met for the method to be accurate, including scattering and absorption agents being uniformly distributed throughout the plume section. The scattering co-efficient over the spectral interval needs to be considered constant or its variation needs to be predictable, and the stack plume must be optically thin, i.e. the radiation scatter must be small compared to incident radiation. It notes a problem that might arise by scattering of radiation from clouds in the background.

A solution to some of these problems is to mount both the source and a detector close to the top of a stack. However, this is usually an extremely hostile environment, where instruments are subject to extreme weather conditions and gases emitted by the stack. Since the source and the detector are relatively sensitive instruments, this can cause problems, and it is not easy to access the instruments for repair and maintenance.

U.S. patent 3,838,925 shows a photoelectric opacity measuring system that is mounted on a smoke stack. It suggests the use of a conventional lamp for illumination. A further installation on a stack is disclosed in the Ryan U.S. patent 4,652,756.

More recent proposals do suggest the use of a laser light source, such as in U.S. patent 5,343,043 (Johnson). This discloses a remote sensor device for monitoring motor vehicle exhaust systems, and is intended to provide high speed sampling. The laser is provided immediately adjacent to the intended path, but there is no discussion of remotely mounting the laser. Given the intended application, remote mounting of the laser would give no significant advantage or benefit.

A more recent patent 5,373,160 is concerned with detection of remote hazardous air pollutants. It directs a laser beam of infrared light along a sight path, to illuminate the gases. A telescope is directed along the sight path and collects light from the gases. An optical filter is coupled to the telescope for selecting a particular optical wavelength or band, and focusing a filtered wavelength on the detector. The invention is intended to provide a long path

infrared spectrometer arrangement, and mentions a path length of up to 6km. As such, the laser would apparently be mounted some distance from a plume from a stack. As noted above, this could lead to various problems in obtaining an accurate reading.

Current and upcoming regulations involve measuring emissions from industrial stacks. Examples of the emission gases that require monitoring include CO_2, CO, NO_X and SO_2 in fossil-fuel combustion processes, NH_3 slippage in ammonium-denox power utilities, HF in aluminium and ceramic production, H_2S and reduced sulphur in pulp and paper plants, CH_4 in natural gas pumping stations, HCl in incinerators, etc.

Standard methods have been developed for extracting samples of stack gas for subsequent analysis in the laboratory. Such methods have dropped from favour because of questions of representativeness of these samples. They have now largely been replaced by continuous extractive methods where the stack gases are continuously sampled from the stack to instruments, located outside the stack, usually separate instruments for each of the stack gases being monitored. Such extractive methods are very complex and cumbersome, requiring heating along the sample lines and elaborate calibration techniques. They also require the cumbersome extractive probe, associated sampling lines and instruments to be located at the stack level, with the resulting exposure to varying weather conditions. They also require maintenance of the instrumentation at locations which are difficult and inconvenient to access. Nevertheless, these extractive methods are the basis of most EPA (Environmental Protection Agency) approved methods in the U.S.A.

The difficulties and inconveniences of these extractive methods have given rise to the development of optical methods of continuous in-situ monitoring of stack gases by transmitting a light beam of appropriate wavelength across all, or part of, the stack, and measuring the optical absorption. Both infrared and ultraviolet wavelengths have been used for this

procedure. The advantages over extractive methods include the elimination of the heated sampling probes. One disadvantage of these remote-sensing optical methods is that the light sources that have been used to date are broad-band, which can result in interferences between the individual gases in the stack gas mixture. For example, in power plant utilities using NH_3-denox procedures it is impossible to distinguish SO_2 from NH_3 using the existing ultraviolet instruments. Similarly, the use of fourier-transform infrared (FTIR) techniques encounters large interferences from CO_2 and H_2O. In addition, regulatory agencies, such as the US EPA, have demanded that calibration of such instruments must be performed in the stack under conditions of the same pressure and temperature as the stack gases since it is known that optical absorption is dependent on both temperature and pressure. Also, separate instruments are still required at each stack location in a multiple stack industrial site.

Although existing optical methods do eliminate the need for heated sampling lines, they still require the presence of the optical instrument at the stack location with the aforementioned difficulties of exposure to inclement weather and large temperature variations and with the difficulties in accessing the instruments for servicing.

SUMMARY OF THE PRESENT INVENTION

In accordance with the present invention, there is provided an apparatus for remote detection of selected trace constituents in a fluid, for example in flue gases. The apparatus is provided, in use, in an installation comprising at least one stack for discharging flue gases to atmosphere and at least one building providing an enclosed area. The apparatus comprises:

a laser for generating a laser beam;

an optical transmission means, for transmitting the laser beam through a fluid, and connected to the laser;

receiving means for receiving a returned laser beam after transmission through the fluid;

a detector means for analyzing the returned laser beam for detecting the presence of any of the selected trace constituents by comparison of the transmitted and returned beams; and

an optical fiber connection means providing a connection between (i) the laser and the optical transmission means, and (ii) the receiving means and the detector means.

The optical transmission means and the receiving means are mounted to one stack adjacent the top thereof and on opposite sides of the stack, whereby the laser beam is transmitted through the flue gases discharged from the stack. The laser and detector means are then located in the enclosed area of the building, so as to be protected by that enclosed area. The transmission means and the receiving means are located remote from the laser and the detection means and are connected to them by the optical fiber connection means.

Preferably, the optical fiber connection means provides a connection between both the laser and the optical transmission means, and between the receiving means and the detector means. Advantageously, the optical fiber connection means then comprises a first optical fiber connecting the laser to the optical transmission means, and connecting the receiving means to the detector means for transmission of a returned beam. Alternatively, two optical fibers may be provided.

Surprisingly, it has been found that a single mode fiber can be used and that the returned beam can be readily focused on the end of the optical fiber, despite its small diameter, so that the single fiber can be used for both transmission and reception. Also, despite the requirement to provide splitter and combiner means at the laser, high efficiencies can be achieved.

The apparatus can include a beam splitter and combiner means connected between the laser and the optical fiber, the beam splitter and combiner means also being connected to the detector means. A reference

cell can then be provided, connected to the beam splitter and combiner means for receiving part of the radiation from the laser, for reference purposes.

Advantageously, the apparatus includes a multiplexer means and a plurality of pairs of transmission and receiving means, the multiplexer means providing a connection between the optical fiber and the pairs of transmission and receiving means, for selective connection to one pair thereof. A multiplexer means can also be provided between a plurality of laser sources and the optical fiber, in addition to or instead of splitter and combiner means, to enable a number of different frequencies to be transmitted through the gas or fluid. Where two optical fibers are required, then two multiplexers would be provided

The transmission and reception means can be provided in various ways. The transmission means and the receiving means can comprise a single unit providing for coaxial transmission and reception, the apparatus further including a retroreflector for reflection of the laser beam transmitted from the transmission means back to the receiving means. In another embodiment, the receiving means is separate from the optical transmission means, for mounting on either side of an area through which a gas or fluid to be analyzed passes, and in this case two optical fibers would be required. In a further embodiment, the transmission means and the receiving means comprise a point source monitor, including a multipass sample cell, providing an extended analytical path. In a fourth embodiment, the transmission means and the receiving means are provided in a stack probe, for monitoring a flow including dust particles, the probe including means for maintaining optical transmission surfaces free of dust particles.

A control unit can be provided that modulates the laser beam, which preferably is an infrared beam generated by a diode laser. The control unit then includes a two tone generator for generating two frequencies that modulate the laser beam. The detector detects a return signal which is the difference in those two frequencies and is connected to the control unit and

the control unit further includes filtering means for filtering out the return signal and a mixer for comparing the return signal to a signal representative of the transmitted signal, to generate a difference signal indicative of the detected concentration of the selected constituents.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

For a better understanding of the present invention and to show more clearly how it may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, which show a preferred embodiment of the present invention and in which:

Figure 1a is a schematic view of an apparatus in accordance with one embodiment of the present invention;

Figure 1b is a schematic view of an apparatus in accordance with a second, preferred embodiment of the present invention;

Figure 2 is a schematic of the controller of the apparatus of the present invention;

Figure 3a is a schematic view of fiber optic connections of the first embodiment of the apparatus of the present invention;

Figure 3b is a schematic view of fiber optic connections of the second embodiment of the apparatus of the present invention;

Figure 4a is a schematic view of fiber optic connections showing the use of multiple lasers in a first embodiment of the invention;

Figure 4a is a schematic view of fiber optic connections showing the use of multiple lasers in a second embodiment of the invention;

Figure 5a is a detailed schematic view of the optical configuration for a remote sensing configuration of the first embodiment;

Figure 5b is a detailed schematic view of the optical configuration for a remote sensing configuration of the second embodiment;

Figure 6 is a detailed schematic view of the optical configuration showing a point source monitor of the apparatus of the present invention;

Figure 7 is a schematic view showing the use of multiple targets for grid monitoring; and

Figure 8 is a schematic view of an application of the present invention to remote monitoring of stack gases.

DESCRIPTION OF PREFERRED EMBODIMENT

Two embodiments of the invention are described, the first being based on the use of separate optical fibers for the transmitted and returned signals and the second relying on a single fiber for both transmission and reception. The single fiber technique is preferred for the reasons given below, although for some applications two fibers are required.

Referring first to Figure 1a, this shows an overall schematic view of the first embodiment of the present invention, and indicates how three, basic, different systems can be configured. The system or apparatus is essentially modular and can be assembled in a variety of configurations, as desired. Thus, in Figure 1a, a laser controller 10 is connected to a control and data acquisition computer 12. The laser controller 10 can be connected to different remote sensing instruments 14, indicated in two different configurations at 14a and 14b. It can also be connected to either a point source monitor 16 or a stack/probe monitor 18. The controller 10 includes the laser and a suitable detector for the returned signal, although not shown in Figure 1a.

The laser controller 10 is linked by both electronic cables and fiber optic cables to other elements of the apparatus. Electronically, the components are coupled by a 50 ohm coaxial cable, as indicated at 20, connecting the controller 10 to the computer 12. Optically, the laser controller 10 is connected to the different devices by pairs of fiber optic cables 22, each comprising a single mode fiber 22a carrying the transmitted laser light to a transmitter and a multimode fiber 22b, carrying the return or received light. Optical coupling offers several advantages. It facilitates operations in adverse and hazardous (combustible) environments. In addition, the very low

gain loss permits the laser and laser controller 10 to be located several hundred metres away from the site at which the actual measurement takes place.

Reference will now be made to Figure 5a, which shows details of a transmitter telescope 70 suitable for the configuration 14a, but with the laser and detector located on the telescope. The connection to the telescope would then be by way of conventional cables and not by optical fibers.

In Figure 5a, the laser 66 is mounted by a laser mount 71 and its output is reflected off a folding flat mirror 72. A beam splitter mirror 74 splits off a small portion, approximately 10 percent of a laser beam, to a secondary detector or reference cell 76. The telescope 70 may be either refractive, reflective or a combination of both. The telescope aperture is given or set by the range of analytical path required; a 10 cm. aperture is required for a 10 - 500 meter base path a 20 cm. aperture is required for 500 - 2,000 meter path.

The main output from the laser continues to a transmission or steering mirror 78. This reflects the output to form a beam 98a travelling to a retroreflector 80 (Figure 1a), which provides a cubic array in known manner, to reflect the beam back along the same path on which it was received. Consequently, the analytical path is twice the base path distance. The returned beam 98b is received by a concave mirror 82, which focuses the beam down to a secondary mirror 84. This mirror 84, in turn, focuses the beam into a main detection cell 86. Within the cell 86, a beam splitter 88 divides the beam into a small portion directed to an eye piece or automatic alignment mechanism 90, and a main portion that passes through to a primary detector 92.

It will be appreciated that the telescope could readily be modified for connection to a remote laser and detector, by removing the laser and the detector and providing appropriate connections for the two optical fibers 22a, 22b.

The second preferred embodiment of the present invention utilizes a single mode fiber but otherwise is similar in many respects to the first embodiment. For simplicity and brevity, similar reference numerals used for the first embodiment are used for the second embodiment, but starting at 200, so that the laser controller 10 becomes laser controller 210, computer 12 becomes computer 212, etc. For brevity, descriptions of common elements are not repeated and the description of the first embodiment is equally applicable.

Referring to Figure 1b, the laser controller 210 includes a beam splitter and combiner 130 having a connection to the laser 266. A signal detector 132 is connected to the beam splitter 130 for receiving a returned beam, while a reference cell 134 is also connected to the beam splitter and combiner 130 for receiving a portion of the original laser beam from the laser 266 for reference.

The remote sensing instrument or telescope 214 is similar to the configuration 14a of the first embodiment. However, just one optical fiber 230 is provided, which is a single mode optical fiber, which is connected between the beam splitter and combiner 130 and the telescope or instrument 214. As before, a retroreflector 280 is provided.

It will be appreciated that, as shown in Figure 1b, the beam splitter and combiner 130 diverts half of the radiation from the laser to the reference cell 134. Correspondingly, the effect of the beam splitter 130 is to cause only half of 50% of the return radiation to reach the signal detector 132; the other half is transmitted to the laser 266, and an optical-isolator is provided that protects the laser from the interfering effects of this radiation. Accordingly, the overall efficiency is only 25%.

However, as compared to the two fiber system of Figure 1a, this is an improvement. Due to the inefficiencies in collecting the returned radiation, typically only 15% efficiency is achieved for the two fiber system. Thus, despite the extra inefficiencies built in by the beam splitter 130, the overall efficiency is in fact greater with a single fiber.

Figure 5b shows details of the optical configuration of the instrument 214. The optical fiber 230 terminates at termination end 231 in a connection unit 286. The unit 286 provides an eye piece 290 and an input/output connection. It includes a beam splitter 288 for diverting a portion of the returned beam to the eye piece 290 for alignment with the retroreflector 280. As before, the telescope assembly includes a concave mirror 282 and a secondary mirror 284.

Unlike the first embodiment of Figure 5a, the laser 66 and related components are omitted, since the laser 66 is provided remotely as laser 266 in the control unit. Instead, the beam is received through the single mode fiber 230 and focused by the mirrors 284/282. The retroreflector 280 by its inherent design returns the beam along exactly the same path. The mirrors 282, 284 ensure that the beam 298 returns along the same path and is focused on the end of the optical fiber 230. Thus, even though a single mode optical fiber 230 has a small cross-section of approximately 10 microns, efficient collection of a returned beam can be obtained, and indeed virtually all the returned beam can be collected and returned back down the optical fiber 230. Even if the end 231 of the optical fiber 230 is slightly misaligned, the optical arrangement is such that the return beam will always exactly traverse the path of the outgoing beam, so such misalignment has no effect.

Reference will now be made to Figure 2 which shows details of the laser controller 10 of the first embodiment; this controller is also applicable to the second embodiment, described below. The controller 10 includes a two tone generator 50. This two tone generator includes a function generator 52 connected to a power splitter 54. The function generator 52 generates a frequency "r". Part of the signal is split off to a frequency doubler and phase adjuster unit 56, where the frequency is doubled to "2r".

The main portion of the signal is fed to a mixer 58, which also has an input connected to a generator 60. The generator 60 generates a frequency "F". The mixer 58 mixes the two signals to create two signals F + r

and F - r. These two signals are amplified in an amplifier 62 and then connected to a laser control unit 64. The laser controller includes the control unit 64 and the actual laser, indicated at 66, controlled by the control unit 64. The laser 66 is a near infrared (NIR) diode laser. The laser control unit 64 provides a thermoelectrically cooled unit for temperature control, for coarse control. Laser emission is obtained by injecting an appropriate current across the diode supplied by a stabilized current source. The laser control unit 64 also provides a ramp generator with a frequency in the range 10-100 kHz to fine tune the emission wavelengths rapidly across the absorption range of interest. A stable repetitive scan facilitates multi scan averaging which in turn improves the sensitivity of the system. The additional frequencies supplied by the two tone generator 50 augment the basic sensitivity of the system. The two tone frequency modulation facilitates data extraction from the FM bands generated. The two signals F + r and F - r are superimposed on the laser driver current by means of a bias T.

Figure 2 indicates a detector at 92, 132 to indicate that the detector could either be mounted on the telescope as in Figure 5a or remotely as in Figure 1b. The signals received by the detector 92, 132 are band filtered and demodulated in a filter unit 94, which also allows for the bias T. The filtered signal 2r' is fed to a mixer 96, which also receives the original signal 2r from the frequency doubler 56. If the detected signal 2r' is the equivalent to the signal 2r fed to the mixer 96 and representative of the original signal, then the difference between the two signals will be 0 and the DC output will be 0. Where an absorption feature distorts the measured signal 2r', then there will be a difference, and a DC output will be provided, which is proportional to the detected difference. The DC output from the mixer 96 is low passed filtered and fed to an analogue digital converter interfaced with the PC based micro computer 12, for averaging, processing, comparison and temperature display.

For fixed frequency amplitudes, the measured DC voltage at the mixer 96 is directly proportional to the concentration of the absorbing gas.

A single laser controller 10 may hold and control several lasers and by means of a beam splitter light can feed light to single or several probes simultaneously. As the controller 10 is linked to a computer, the computer, in addition to manipulating and storing data, can also electronically control the operation of the controller 10.

Referring now to Figure 6, this shows a remote sensing probe or instrument 18, suitable for continuous, non-extractive stack and/or duct monitoring. This has a base 102, in which a pair of off-axis parabolic mirrors 103, 104 are mounted. The single mode cable 22a from the laser provides a point source of radiation that is focused by the mirror 103 to a beam 106. A cubic retroreflector 108 reflects this beam back as indicated at 107. The beam 107 is reflected by the second parabolic mirror 104 on to the end of the multimode fiber 22b.

A calibration cell 110 is located to include the outward and return beam paths 106, 107. At 112, an inlet and an outlet are provided for calibration gas, for the calibration cell 110.

The main working section of the stack probe 100 is indicated at 114. It is suitably perforated to permit gas of interest to pass through it. The working section 114 has a length of 100cm., to give an effective, analytical path of 200cm.

The retroreflector 108 is enclosed in an end housing 116 connected to a gas supply duct 118. A supply of clean, cool gas is provided through the duct 118, to maintain the retroreflector 108 cool and clean. This can also be connected adjacent the cell 110, to ensure that it remains clean. The flow is such as to provide the necessary cleaning effect, without significantly disrupting flow of the gas of interest through the working section 114.

While Figure 6 shows separate connections for the input beam and the return beam, with associated off-axis parabolic mirrors 103, 104, this is not essential. It can be configured for use with the second embodiment of the invention, where a single optical fiber is provided. In this

case, a single input connection can be provided similar to that shown in Figure 5b, and the mirrors 103, 104 omitted. A focus arrangement can be provided, and the retroreflector 108 configured to ensure that the return beam retraces exactly the outgoing beam. This again should ensure that the return beam is focused on to the end of the optical fiber.

The point source monitor 16 uses a light folding multi path analytical cell. The optical path in the cell may be adjusted to accommodate sensitivity requirements. Low volume multipath cells with a fixed optical path length of 12.5 and 50.4 metres are presently used by the applicant, but other configurations can be developed for other applications. Path lengths of up to 100 metres can be provided.

The overall system is a high resolution spectrometer that can detect and measure a large range of trace gases and ambient air. It can monitor one or several gases simultaneously, and as such is a powerful tool suitable for applications in air quality control, emission control and industrial process control.

The remote sensing configuration of Figures 1a or 1b is suitable for measuring pollutant trace gases in ambient air. In an open environment, it can be installed on roof tops, and used as a monitor to record trends in air quality. It can also be used indoors. For large factory settings, the remote sensing configuration can be installed immediately below the ceilings of the manufacturing facilities. For smaller structures, the point source monitor 16 can be used for individual rooms or at an air circulation facility.

The system can be used for self-policing and as a potential standard for a regulatory market.

The configuration 14a or 214 can also be installed across a road for monitoring a car, and exhaust plumes in passing traffic. This system can be combined with an automatic camera, so as to record and identify vehicles whose exhausts offend set regulatory limits.

The stack monitor probe 18 and the point source monitor 16 can be installed on a stack to monitor industrial exhausts and flue gases. The point source monitor 16 can monitor potential pollution "hot spots".

Referring to Figure 7, the remote sensing instrument 14a can be installed on a mechanized mount, indicated at 120. It can then be provided with a plurality of reflectors 80. The mount 120 can than be used to focus the beam on each reflector 80 in turn. This provides a multi-target setting, which is ideal for fence and grid monitoring. This allows the user to map the behaviour of an area of interest and helps identify "hot spots". Fence and grid monitoring are suitable for landfill sites and factory settings.

Practically all of the trace gases in industrial exhaust are due to chemical reactions, the system of the present invention can be used for process control feedback. Fluctuations in the concentration of some effluent gases and/or the appearance of new or unwanted components are often an indication of reaction efficiencies or reactions which are not proceeding ideally. Feedback from such information can be used to control the reaction, to maintain it at an efficient level and/or to prevent the production of pollutants or at least keep pollutant levels within regulatory limits. This can lead to more profitable operation of a plant, while reducing pollution levels.

Referring to Figure 3a, this shows a multiplexing arrangement. For exemplary purposes, this shows two stack probe monitors indicated at 18a and 18b, and a laser controller, here indicated at 10a connected to a controlling computer 12a (the suffix 'a' being used to distinguish from the earlier Figures).

Now, in accordance with the present invention, an optical multiplexer is provided at 24. This multiplexer 24 comprises first and second multiplexers 25 and 26, ganged together. Thus, the optical multiplexer 25 has a plurality of connections 25a on one side and a single connector 25b on the other side. The connector 25b is mounted for sliding movement, to permit its alignment with a selected one of the connections 25a. Correspondingly, the multiplexer 26 has a plurality of connections 26a on one

side and a single connector 26b on the other side. The connection 26b is again mounted for sliding movement.

A connection bar 28 connects the two single connectors 25b, 26b, to form a switching mechanism.

Just one single mode fiber 22a connects a laser to the multiplexer 25 and correspondingly a single multimode fiber 22b connects the multiplexer 26 to a laser detector at the controller 10a.

On the other side of the multiplexers, there are a plurality of single mode fibers 30 connecting the connections 25a to appropriate devices, such as the probes 18a and 18b. Correspondingly, there are a plurality of multimode fibers 32 for communicating the returned light to the connections 26a of the multiplexer 26. Thus, a selected one of the probes connected to the multiplexers can be connected to the laser controller 10a.

It will be appreciated that the multiplexers 25, 26 can be reversed for selectively connecting one of a number of lasers to a single probe, for example, on a time sharing basis. This would enable monitoring of different species at different times. Alternatively, additional multiplexes can be provided connected to the connections 25b, 26b and a plurality of lasers connected to inputs of the additional multiplexers. Then, a selected laser can be connected to a selected sensing unit.

Referring to Figure 3b, this shows a multiplexing arrangement for a single fiber configuration. This is shown in association with stack probes or monitors 218a and 218b. A single multiplexer 225 is provided connected by a single mode optical fiber 230 to the laser controller 210. The optical fiber 230 comprises a first portion 230a providing a connection to the multiplexer 225 and second portions 230b connecting the outputs 225 to the probes 218a and 218b. The multiplexer 225 has an input connector 226 that can be moved to a selected one of its outputs. As shown, the multiplexer provides a connection to the probe 218a with the probe 218b being inactive. The laser controller 210 can be as described above.

Reference will now be made to Figure 4a, which shows the incorporation of beam splitters and combiners, which can be used instead of multiplexers for plural laser sources. Here, the multiplexers are also shown and similar components are given the same reference numerals as in Figure 3a. To distinguish from earlier figures, the laser controller is here identified by the reference 10b.

The laser controller 10b includes at least two lasers 40, 41, connected through respective beam splitters 42 and 43. A fiber optic beam splitter is a device that splits the incoming light equally between two output fibers, so that each receives 50% of the input light.

Here, as shown, the outputs of the two beam splitters 42, 43 are connected to a beam splitter or combiner 44 that serves to combine the two half signals from the two lasers 40, 41. The other outputs from the beam splitters 42, 43 are connected to reference cells, as indicated at 45 and 46.

As before, a single mode fiber 22a provides a connection to the multiplexer 25, and a multimode fiber 22b provides a connection back from the multiplexer 26 to a signal detector indicated at 48.

Referring now to Figure 4b, this shows an arrangement similar to Figure 4a, but again in accordance with the second preferred embodiment with just one, single mode optical fiber 230, again shown as a first portion 230a and second portion 230b. Stack probes 218a and 218b are shown as in Figure 3b. Here just the single multiplexer 225 is required.

The laser controller, indicated at 210b includes beam splitters 242, 243 and 244. A pair of lasers 240 and 241 are connected to the beam splitters and combiners 242, 243. The beam splitters and combiners 242, 243 are connected to a signal detector 132 and to reference cells indicated at 245.

This arrangement enables either one of the lasers 240, 241 to be connected to a selected one of the sensing instruments connected to the outputs of the multiplexer 225, here the probe to 218a. Instead of the beam splitter 244, if it is required to use a large number of lasers, another

multiplexer can be used, configured to selectively connect one laser source to the optical fiber 230a.

The arrangements of Figures 4a and 4b enables a number of different frequencies to be transmitted to a single probe simultaneously, for simultaneous detection of different gases and components of interest.

Reference will now be made to Figure 8, which shows an implementation of the system of the present invention. This shows a schematic implementation of a factory installation, including buildings 122, housing offices, administrative and control equipment. It also includes a number of stacks for flue or other process gases, of which two are indicated at 124.

The system with the fiber optic network configuration of Figure 3a and/or 3b is installed in this case, but for simplicity the description is in relation to the first embodiment of Figure 3a. The system control and acquisition computer 12a and the laser controller 10a are located in one of the buildings 122. These would then be connected to the fiber optic multiplexers 25 and 26 by the single and multiple mode optical fibers (not shown in Figure 8), or just single mode fibers and a single multiplexer 225 in the second embodiment.

The optical multiplexers 25, 26 or 225 are then in turn connected to the single and multiple mode optical fibers 30, 32 or 230.

Here, one stack 124 is equipped with the remote sensing configuration 14a or 214. As shown, the telescope 70 is mounted on one side of the stack and the reflector 80 is mounted on the other. One pair of optical cables 30, 32 is connected to the telescope 70, or single fiber 230 in the case of the configuration 214.

For the other stack 124, by way of example, there is shown the remote sensing configuration 14b of Figure 1a. This includes a transmitting telescope 94 on one side and a receiving telescope 96 on the other side. Again, a pair of optical fibers 30, 32 is provided.

This arrangement enables the sensitive equipment, e.g. the laser and the detector, to be located in the buildings 122, where repair and maintenance are readily provided. Further, these instruments are not then located in the hostile environment at the top of the stacks 124. The gases emitted from the stacks 126 can include many chemicals that are corrosive etc., which could damage the equipment. Here, at worst, such damage will be incurred by the relatively simple and inexpensive remote sensing equipment, which can be replaced if necessary.

I CLAIM:

1. An apparatus for remote detection of selected trace constituents in flue gases, in use with an installation comprising at least one stack for discharging flue gases to atmosphere and at least one building providing an enclosed area, the apparatus comprising:

a laser for generating a laser beam;

an optical transmission means, for transmitting the laser beam through a flue gas, and connected to the laser;

a receiving means for receiving a returned laser beam after transmission through the flue gas;

a detector means for analyzing the returned laser beam for detecting the presence of any of the selected trace constituents by comparison of the transmitted and returned beams; and

an optical fiber connection means providing a connection between (i) the laser and the optical transmission means, and between (ii) the receiving means and the detector means;

wherein the optical transmission and the receiving means are mounted to one stack, adjacent the top thereof, whereby the laser beam is transmitted through the flue gases discharged from the stack, and wherein the laser and the detector means are located in the enclosed area of the building, whereby the laser and the detector means are protected by the building, the optical transmission means and the receiving means are remote from the laser and the detection means and are connected thereto by the optical fiber connection means.

2. An apparatus as claimed in claim 1, wherein the optical fiber connection means comprises a first optical fiber connecting the laser to the optical transmission means, and connecting the receiving means to the detector means for transmission of a returned beam.

3. An apparatus as claimed in claim 2, wherein the optical fiber is a single mode fiber.

4. An apparatus as claimed in claim 3, which includes a beam splitter and combiner means connected between the laser and the optical fiber, the beam splitter and combiner means also being connected to the detector means.

5. An apparatus as claimed in claim 4, which additionally includes a reference cell connected to the beam splitter and combiner means for receiving part of the radiation from the laser, for reference purposes.

6. An apparatus as claimed in claim 5, which includes a plurality of lasers, and, for each laser, a respective beam splitter and combiner means connected thereto and a reference cell and a detector both connected to the beam splitter and combiner means, and wherein the apparatus includes a first multiplexer means having a plurality of connections on one side, each connected to one of the beam splitters and combiner means, and a connection on the other side to the transmission means and the detector means.

7. An apparatus as claimed in claim 6, which includes a second multiplexer means having an input connected to the other side of the first multiplexer means, and a plurality of outputs and wherein the apparatus includes a plurality of pairs of transmission means and receiving means, each pair of transmission and receiving means being connected to one output of the second multiplexer means.

8. An apparatus as claimed in claim 1, which includes at least one of: (a) multiplexer means and a plurality of pairs of transmission means and receiving means, the multiplexer means providing a connection between

the optical fiber connection means and the pairs of transmission and receiving means for selective connection to one pair thereof, and (b) a plurality of lasers and beam splitter and combiner means connecting the lasers to the optical fiber connection means for simultaneous transmission and reception of at least two different laser beams.

9. An apparatus as claimed in claim 1, wherein the optical fiber transmission means comprises a first optical fiber connecting the laser to the optical transmission means, and a second optical fiber transmitting a returned beam from the receiving means to the detector means, wherein the apparatus includes a plurality of pairs of optical transmission means and receiving means, wherein each of the first and second optical fibers comprises a first portion and a plurality of second portions, wherein the apparatus further includes a first optical multiplexer having an input connected to the first portion of the first optical fiber, the other end of which is connected to the laser, wherein the plurality of second portions of the first optical fiber provide connections between the first multiplexer and the optical transmission means, wherein a second multiplexer has an output connected to the first portion of the second optical fiber, the other end of which is connected to the detector means, and wherein the plurality of second portions of the second optical fiber provide connections between the second multiplexer and the receiving means, the first and second multiplexers being operable to connected a selected pair of the transmission means and the receiving means to the laser and the detector means.

10. An apparatus as claimed in claim 7, which includes a plurality of lasers, and beam splitter and combiner means for combining the outputs from the lasers for communication through the first optical fiber and wherein each laser has an associated beam splitter and combiner means to which its output is connected, each of which beam splitter and combiner

means has one output providing a connection to the first optical fiber and another output connected to a reference cell.

11. An apparatus as claimed in claim 1, wherein the receiving means is separate from the optical transmission means, for mounting on either side of an area through which a fluid to be analyzed passes, and wherein the optical fiber connection means comprises a first, transmission optical fiber connecting the laser to the optical transmission means, and a second, return optical fiber transmitting a returned beam from the receiving means to the detector means.

12. An apparatus as claimed in claim 9, wherein the transmission means and the receiving means comprise a point source monitor, including a multipass sample cell, providing an extended analytical path and wherein the optical fiber connection means comprises a first, transmission optical fiber connecting the laser to the optical transmission means, and a second, return optical fiber transmitting a returned beam from the receiving means to the detector means.

13. An apparatus for the remote detection of selected trace constituents in flue gases, in use with an installation comprising at least one stack for discharging flue gases to atmosphere and at least one building providing an enclosed area, the apparatus comprising:

a laser for generating a laser beam;

a plurality of pairs of an optical transmission means for transmitting the laser beam through a flue gas, and a receiving means for reciving a returned laser beam after transmission through the flue gas;

a detector means for analyzing the returned laser beam for detecting the presence of any of said selected trace constituents for comparison of the transmitted and returned beams;

a multiplexer means providing a connection between the laser and the optical transmission means and between the receiving means and the detector means; and

an optical fiber connection means providing a connection between a laser and the optical transmission means and between the receiving means and the detector means;

wherein each pair of an optical transission means and a receiving means is mounted to one stack adjacent the top thereof, whereby a laser beam is transmitted through the flue gases discharged in the stack, and wherein the laser, the detector means and the multiplexer means are located in the enclosed area of the building, whereby the laser, the detector means and the multiplexer means are protected by the building, the pairs of optical transmission means and detection means are remote from the laser and the detection means and are connected thereto by the optical fiber connection means, and the multiplexer means can selectively connect the laser to any one pair of the optical transmission means and the detector means.

14. An apparatus as claimed in claim 13, which includes a plurality of lasers, wherein the beam splitter and combiner means is connected to the lasers, wherein each laser has a respective reference cell connected to the beam splitter and combiner means for receiving a portion of the radiation thereof for reference purposes, and wherein a detector is provided for each laser, connected to the beam splitter and combiner means for receiving a portion of the radiation returned back to the detector.

15. An apparatus as claimed in claim 13, which includes a plurality of lasers and beam splitter and combiner means providing a connection between the lasers and the multiplexer means.

16. An apparatus as claimed in claim 15, wherein the beam splitter and combiner means provides an output for a reference signal from each laser and includes reference cell means connected to the output of the beam splitter and combiner means.

17. An apparatus as claimed in claim 16 wherein the beam splitter and combiner means receives the returned laser beam and includes a further output connection connected to the detector means.

18. An apparatus as claimed in claim 16, wherein the multiplexer means has a first multiplexer having a plurality of connections on one side, connected to the transmission means and the reeiving means, and having a first pair of connection ports on the other side, and a second multiplexer comprising a plurality of connections on one side connected to the lasers and the detector means, and a second pair of connection ports on the other side connected to the first pair of connection ports of the first multiplexer.

19. An apparatus as claimed in claim 15, wherein the multiplexer means has a plurality of connections on one side connected to the transmission means and the receiving means and a connection port on the other side thereof, and wherein the apparatus includes a plurality of beam splitter and combiner means which are connected together to form a single connection connected to the connection port of the multiplexer means and which are connected to the lasers and to the detector means, whereby each laser beam is connected through to the multiplexer means and a return beam is connected through to the detector means, and wherein the beam splitter and combiner means provide outputs for reference signals from the lasers, the apparatus including reference cell means connected to said outputs.

20. An apparatus for the remote detection of selected trace constituents in a fluid, the apparatus comprising:

a laser for generating a laser beam;

a plurality of probes selected from: a pair of an optical transmission means for transmitting the laser beam through the fluid and a receiving means for receiving a returned laser beam after transmission through the fluid; a point source monitor including a multipass cell, providing an extended analytical path; and a stack probe for monitoring fluid flow including dust particules, the probe including means for maintaining optical transmission services free of dust particles;

a detector means for analyzing a return laser beam for detecting the presence of any of the selected trace constituents by comparison of the transmitted and returned beams;

a multiplexer means for providing selected connection between one of the probes and the laser and the detector means; and

optical fiber connection means providing a connection between the multiplexer means and the probes, and between the multiplexer means and each of the detector means and the laser.

ABSTRACT OF THE DISCLOSURE

An apparatus for remote detection of selected trace constituents in a fluid, for example flue gases from a stack, has a laser for generating a laser beam. The laser beam is transmitted through the fluid and the returned laser beam is detected after transmission through the fluid. A detector receives the returned laser beam, to detect the presence of any of the selected trace constituents, by comparison of the transmitted and returned beams. An optical fiber connection means, which can comprise either a single optical fiber or a pair of optical fibers, provides a connection between at least one of (i) the laser and a transmitter for the laser beam, and (ii) a receiver for the laser beam and the detector. This enables the detector and the laser to be located remotely and away from hostile environments.

FIGURE 1a LASAIR SYSTEM CONFIGURATIONS

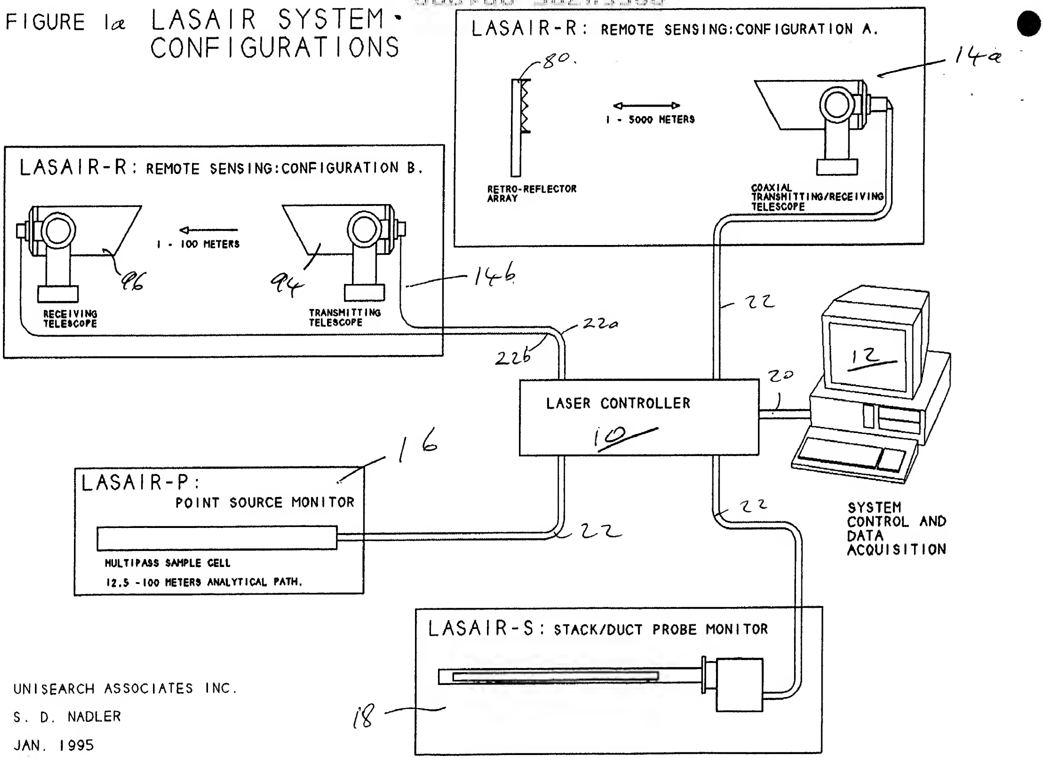

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FIGURE 1b

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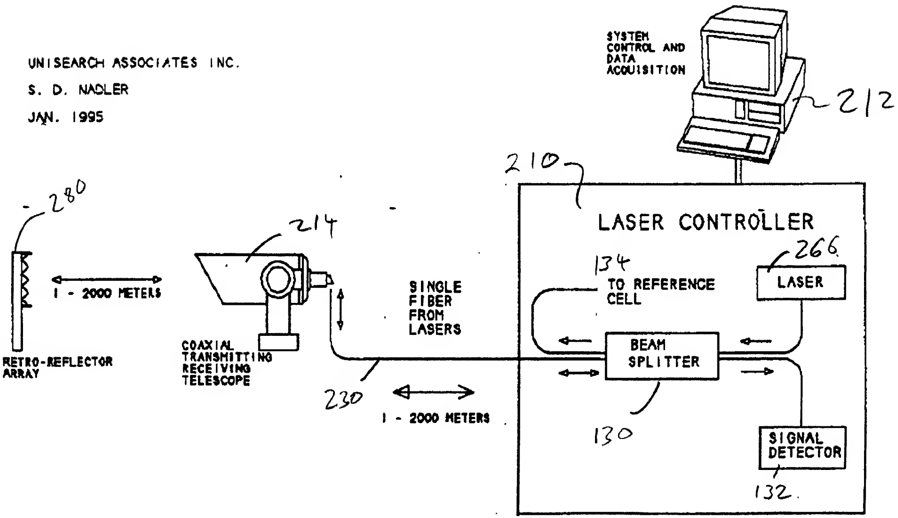

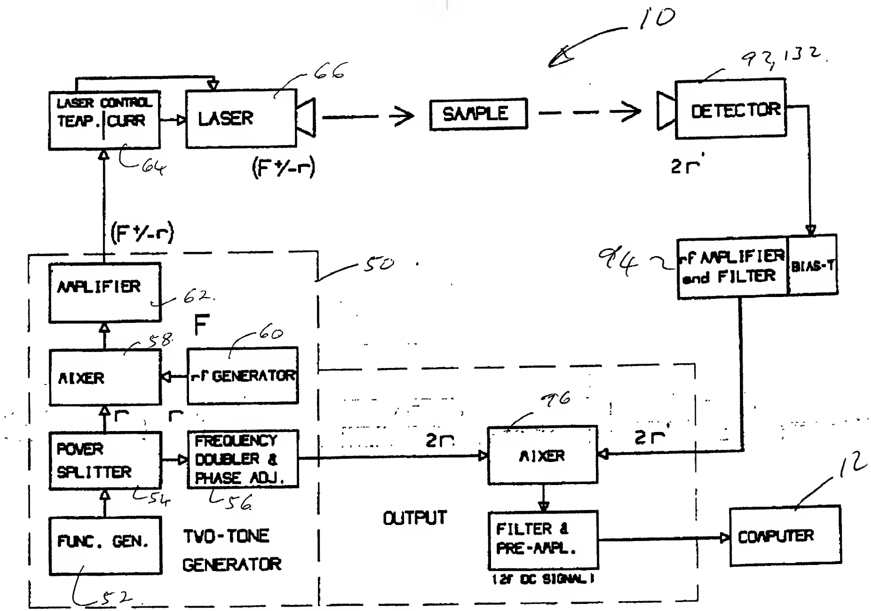
10
LASER CONTROL
TEMP.
CURR
64
LASER
66
(F+/-r)
SAMPLE
DETECTOR
92, 132
2r'
BIAS-T
rf AMPLIFIER and FILTER
94
(F+/-r)
50
AMPLIFIER
62
F
MIXER
58
rf GENERATOR
60
r
r
POWER SPLITTER
54
FREQUENCY DOUBLER & PHASE ADJ.
56
FUNC. GEN.
52
TWO-TONE GENERATOR
2r
MIXER
76
2r'
OUTPUT
FILTER & PRE-AMPL.
(2f DC SIGNAL)
COMPUTER
12

FIGURE 2

FIGURE 3a LASAIR SYSTEM: FIBER OPTICS NETWORK CONFIGURATION

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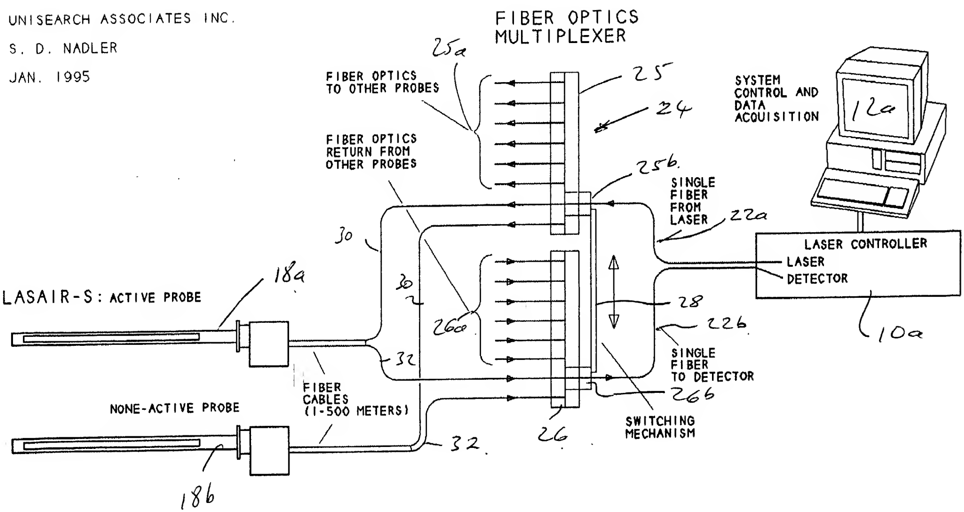

FIGURE 3b LASAIR SYSTEM: FIBER OPTICS NETWORK CONFIGURATION
SINGLE TRANSMIT/RECEIVE FIBER OPERATION

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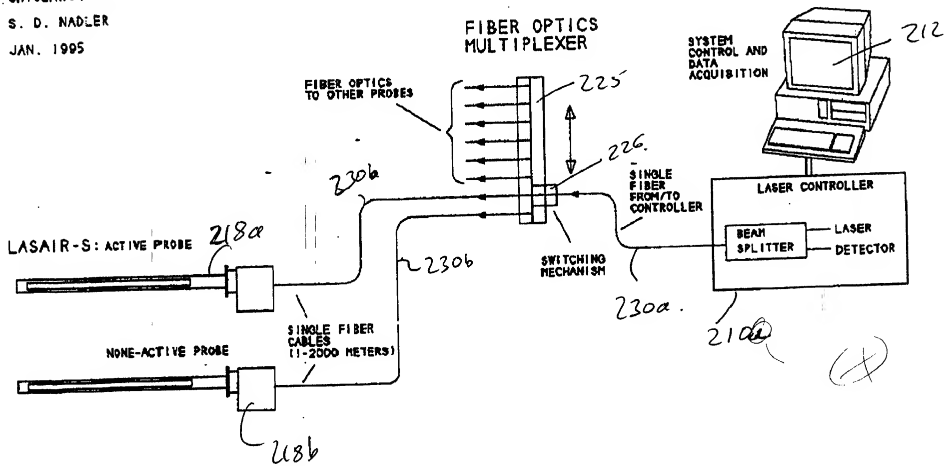

FIGURE 4a LASAIR SYSTEM: FIBER OPTICS NETWORK CONFIGURATION MULTI-LASER OPERATIONS BY USE OF FIBEROPTICS BEAM-SPLITTERS

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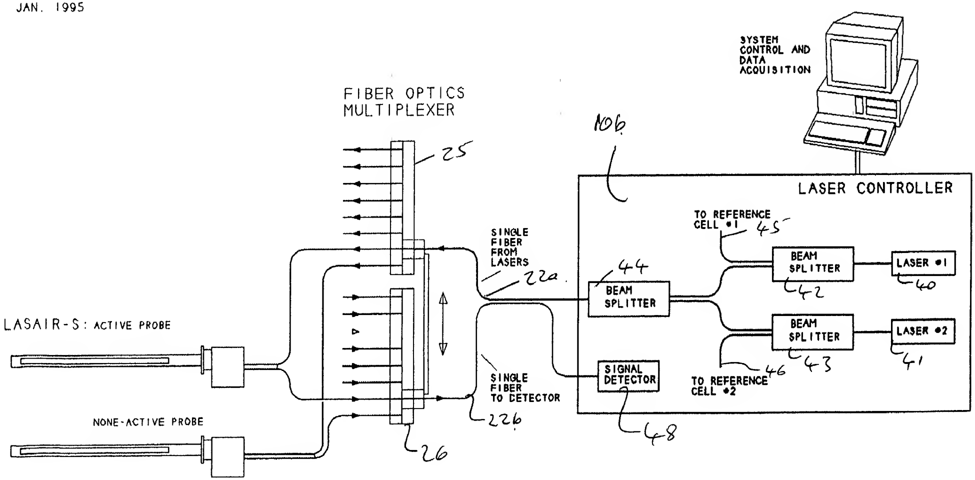

FIGURE 4b LASAIR SYSTEM: FIBER OPTICS NETWORK CONFIGURATION MULTI-LASER OPERATIONS BY USE OF FIBEROPTICS BEAM-SPLITTERS AND SINGLE FIBER CABLES FOR TRANSMIT/RECEIVE OF ANALYTICAL LASER BEAM.

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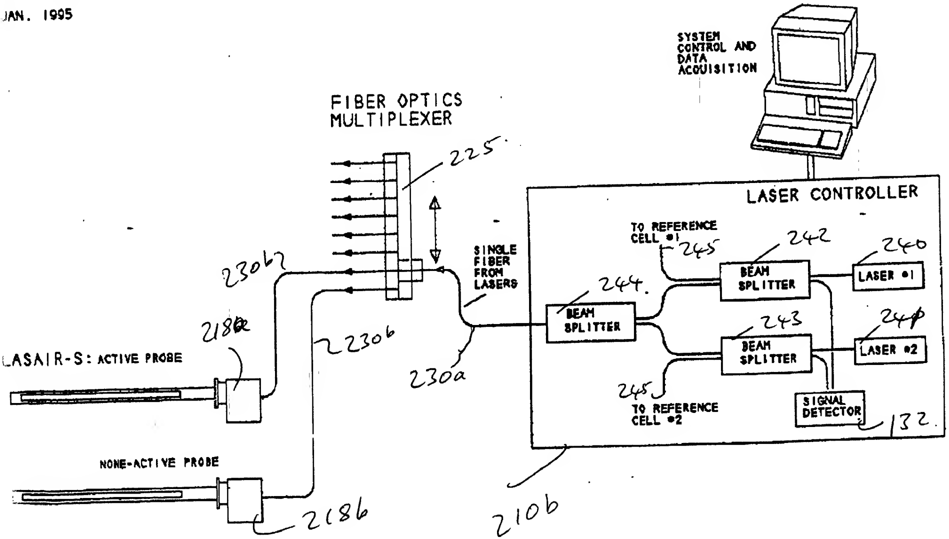

FIGURE 5a.

LASAIR-R OPTICAL CONFIGURATION

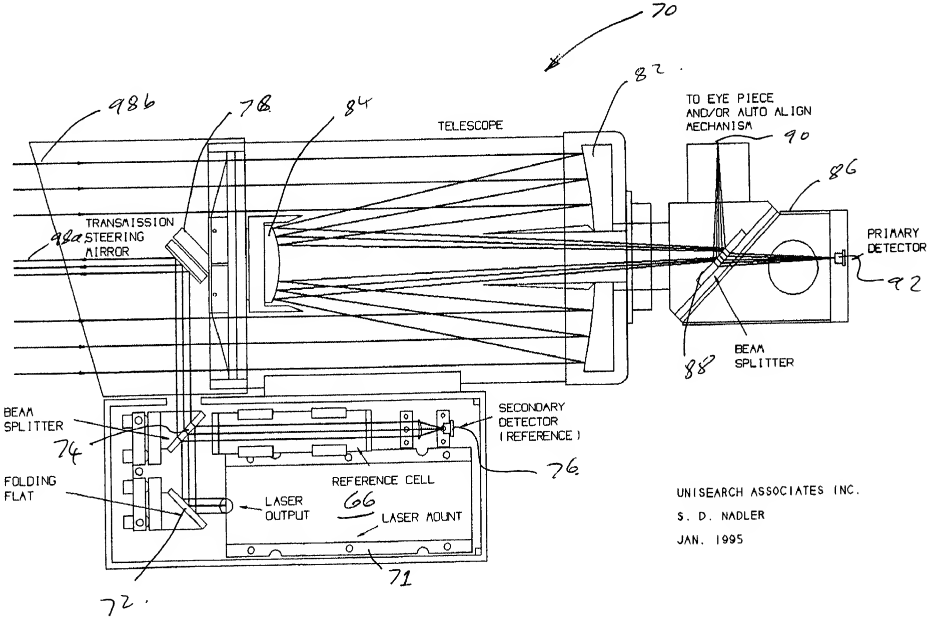

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FIGURE 56

LASAIR-R OPTICAL CONFIGURATION

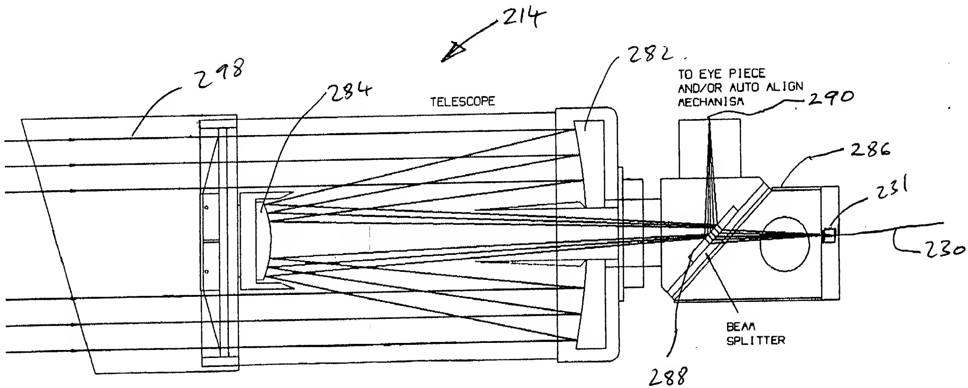
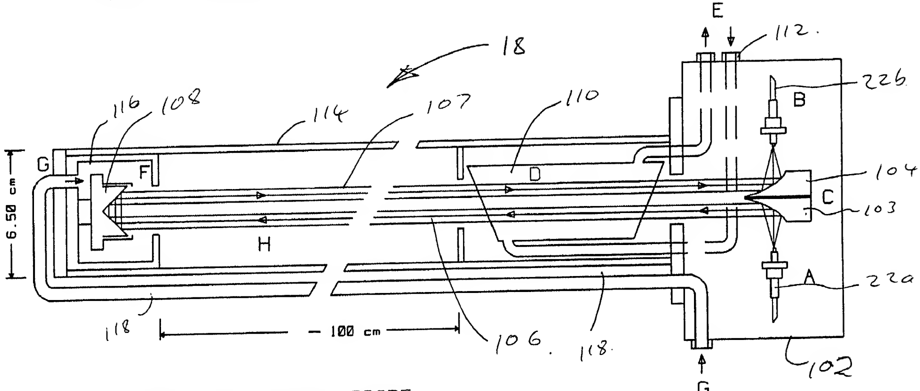


FIGURE 6 LASAIR-S OPTICAL CONFIGURATION



REMOTE FIBER OPTICS STACK PROBE

A. SINGLE MODE FIBER FROM LASER

B. MULTIMODE FIBER TO DETECTOR

C. OFF-AXIS PARABOLIC MIRRORS

D. CALIBRATION CELL

E. CALIBRATION GAS. INLET/OUTLET

F. RETROREFLECTOR

G COOLING AND CLEANING AIR FLOW

H TWO METERS ANALYTICAL OPEN PATH

FIGURE. 7

LASAIR SYSTEM: MULTI-TARGET GRID MONITORING

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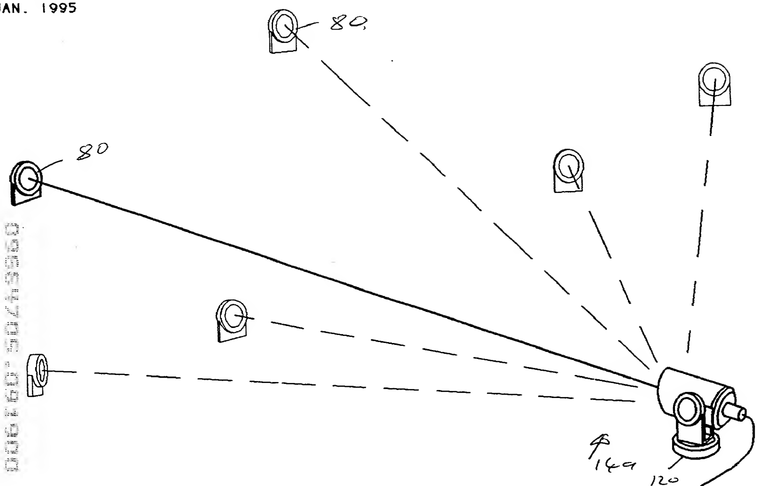
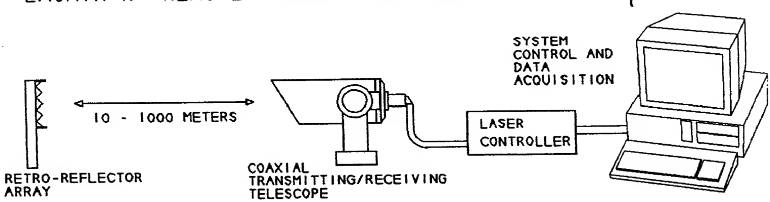


LASAIR-R: REMOTE SENSING CONFIGURATION



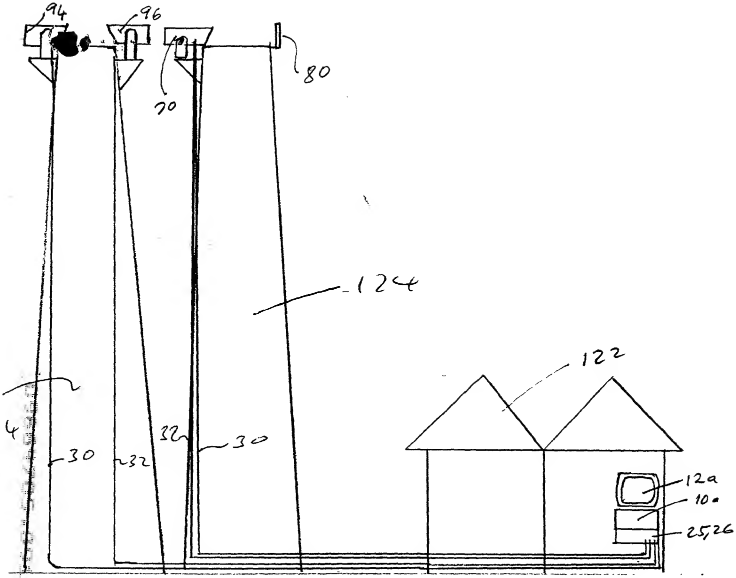


Figure 8.

DECLARATION FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

METHOD AND APPARATUS FOR MONITORING TRACE CONSTITUENTS IN A FLUID

the specification of which (check one)
X is attached hereto was filed on ________ as Application Serial No.________
and was amended on ________

I hereby state that I have reviewed and understand the contents of the above identified specifications, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, S1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, S119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s) **Priority Claimed**

(Number)	(Country)	(Day/Month/Year Filed)	Yes	No
(Number)	(Country)	(Day/Month/Year Filed)	Yes	No

Additional applications identified on attached sheet.

I hereby claim the benefit under Title 35, United States Code, S120 of any United States Application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code S112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, S1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application.

Application Serial No.	Filing Date	Status - Patented, pending, abandoned
Application Serial No.	Filing Date	Status - Patented, pending, abandoned

Additional applications identified on attached sheet.

I hereby appoint the following attorneys and/or agents to prosecute this application and to transact all business in the Patent and Trademark Office in connection therewith:

Daniel R. Bereskin	22,257	C. Lloyd Sarginson	29,245	Robert B. Storey	33,108
Richard J. Parr	22,836	Timothy J. Sinnott	31,083	Linda M. Kurdydyk	34,971
H. Roger Hart	26,426	H. Samuel Forst	31,696	Robin Coster	38,016
David W.R. Langton	27,747	Phillip Mendes da Costa	33.106	Michael E. Charles	36,416
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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with knowledge that wilful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such wilful false statements may jeopardize the validity of the application or any patent issued thereon.

FULL NAME OF SOLE OR FIRST INVENTOR	INVENTOR'S SIGNATURE	DATE
SHACHAR NADLER	Nadler S	July 17th, 1995
RESIDENCE 181 Longwood Drive, Bolton, Ontario, Canada L7E 4A3		CITIZENSHIP Canadian/Israeli
POST OFFICE ADDRESS same as above		

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STATEMENT UNDER 37 CFR 3.73(b)

Applicant/Patent Owner: Unisearch Associates Inc.

Application No./Patent No.: 08/508,505 Filed/Issue Date: July 28, 1995

Entitled: METHOD AND APPARATUS FOR MONITORING TRACE CONSTITUENTS IN FLUE GASES, UTILIZING A LASER BEAM

Unisearch Associates Inc. , a Canadian Corporation ,

(Name of Assignee) (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that it is:

1. [x] the assignee of the entire right, title, and interest; or

2. [ ] an assignee of an undivided part interest

in the patent application/patent identified above by virtue of either:

A. [x] An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the Patent and Trademark Office at Reel 7600, Frame 0904, or for which a copy thereof is attached.

OR

B. [ ] A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as shown below:

1. From:________ To:________
The document was recorded in the Patent and Trademark Office at
Reel _____, Frame _____, or for which a copy thereof is attached.

2. From:________ To:________
The document was recorded in the Patent and Trademark Office at
Reel _____, Frame _____, or for which a copy thereof is attached.

3. From:________ To:________
The document was recorded in the Patent and Trademark Office at
Reel _____, Frame _____, or for which a copy thereof is attached.

[ ] Additional documents in the chain of title are listed on a supplemental sheet.

[x] Copies of assignments or other documents in the chain of title are attached.
[**NOTE**: A separate copy (*i.e.*, the original assignment document or a true copy of the original document) must be submitted to Assignment Division in accordance with 37 CFR Part 3, if the assignment is to be recorded in the records of the PTO. See MPEP 302-302.8]

The undersigned (whose title is supplied below) is empowered to sign this statement on behalf of the assignee.

September 15, 2000
Date

[signature]
Signature

Stephen M. Beney, Reg. No. 41,563
Typed or printed name

Patent Agent
Title